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Barcelona Supercomputing Center
Centro Nacional de Supercomputación
EXCELENCIA SEVERO OCHOA
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Tailored seasonal climate predictions for wind energy users

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SPECS
Seasonal-to-decadal climate Prediction for the improvement of European Climate Services
EUPORIAS
GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
NEW EUROPEAN WIND ATLAS
newa

Motivation

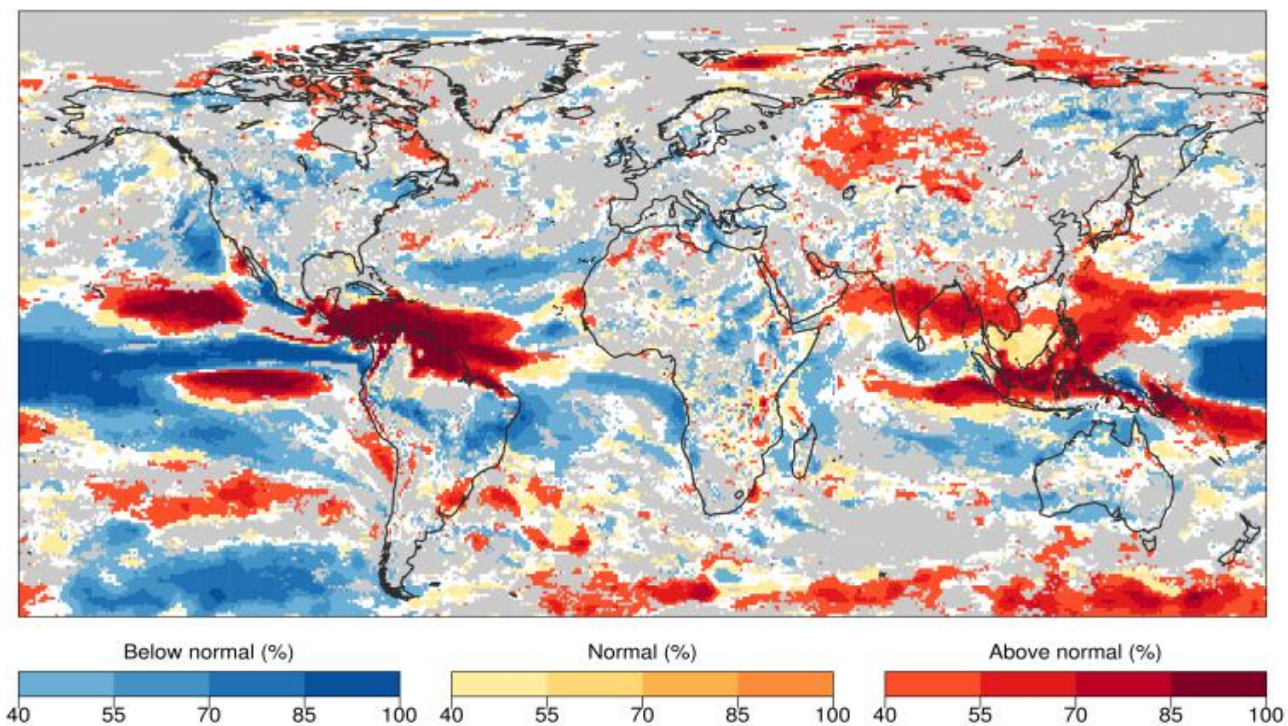
- From monthly to decadal time scales current energy practices assume that future will be a repetition of the **retrospective climatology.**

- The available seasonal predictions can provide additional value **for wind energy applications**
  - Maintenance works
  - Grid management
  - Financial issues

- Limited application because this information is **untailored** and **hard to** incorporate in a useful manner

Objective

Goal: assessment of the forecast quality of the seasonal prediction systems to produce usable information for the wind industry.



ECMWF S4 10-m wind speed seasonal forecast for JJA 2015 initialized the 1st of May. The most likely wind speed category (below-normal, normal or above normal) and its percentage probability to occur is shown. White areas show where the probability is less than 40 % and approximately equal for all three categories. Grey areas show where the climate prediction model doesn't improve the climatology.

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1. Evaluation of different **bias-adjustments** techniques

2. F**orecast quality assessment** of the bias-corrected seasonal predictions

3.Generation of **wind power capacity factor** seasonal predictions

Seasonal forecasts

- **Variables**: 10m wind speed and 2m temperature
- **Forecast system**: ECMWF S4 (51-members)
- **Season:** December-January-February (1 lead time)
- **Period** : 1981-2014
- **Reference dataset**: ERA- Interim

As illustration, seasonal predictions in a region in **Canada,** where wind farms are located, has been selected.

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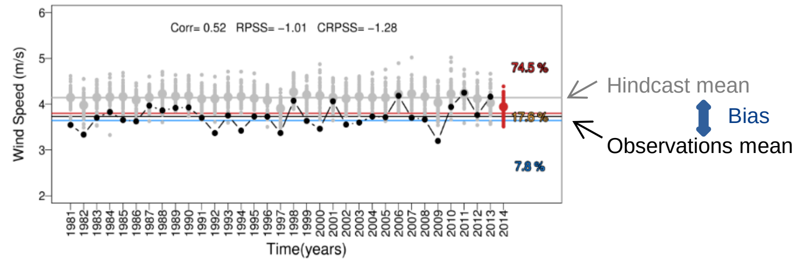
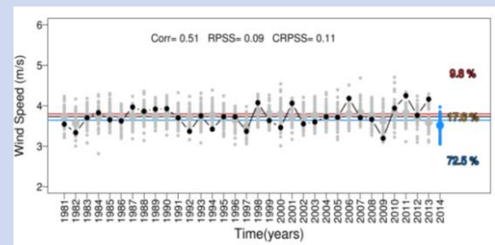
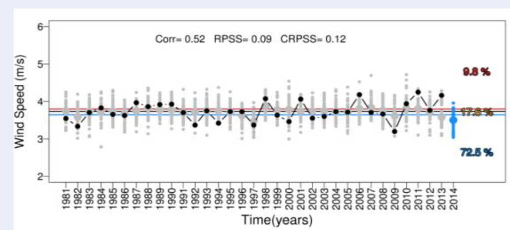
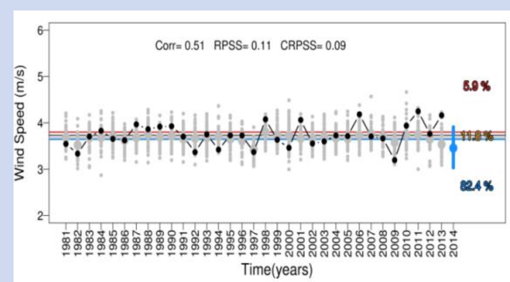
Raw data



Method	Equation	Description	Result
Simple bias correction	$y_{j,i} = (x_{ij} - \bar{x})\frac{\sigma_{ref}}{\sigma e} - \bar{o}$	Based on the assumption that both the reference and forecasted distribution are well approximated by a Gaussian distribution.	
Calibration method	$y_{j,i} = \alpha x_i + \beta z_{ij}$	Variance inflation modifies the predictions to have the same interannual variance as the reference dataset and corrects the ensemble spread to improve the reliability.	
Quantile mapping	$y_{j,i} = (ecdf^{ref})^{-1} ecdf^{mod}(x_{ij})$	It determines for each forecast to which quantile of the forecast climatology it corresponds, and then they are mapped to the corresponding quantile of the observational climatology.	

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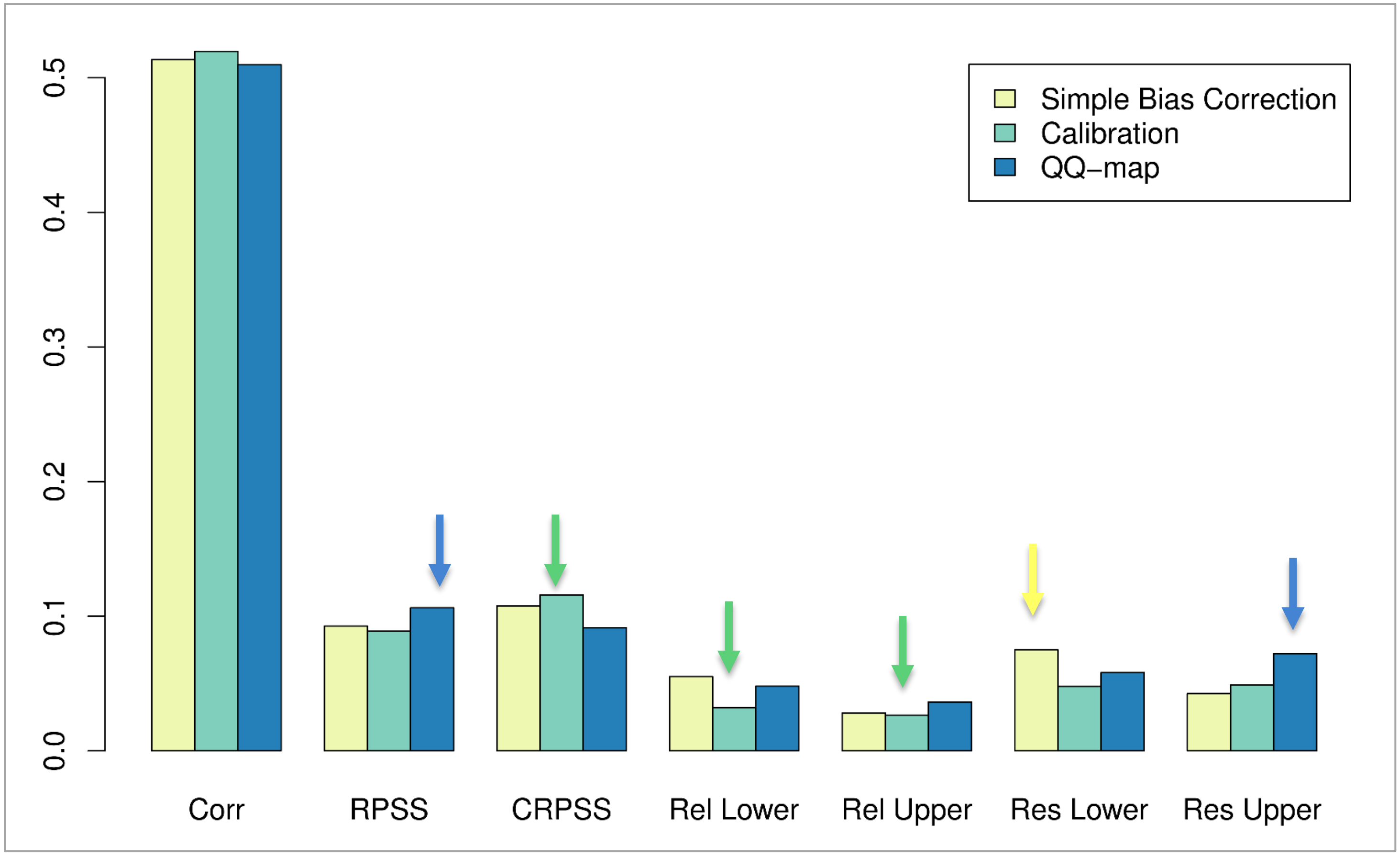
2. Forecast quality assessment



- Variations between the scores are low for the three different bias-adjustments.
- Calibration method produce the best CRPSS and reliability for the below-normal category and above normal category, however the forecasts corrected with the quantile mapping method produce higher RPSS.

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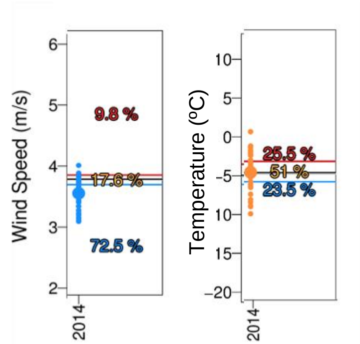
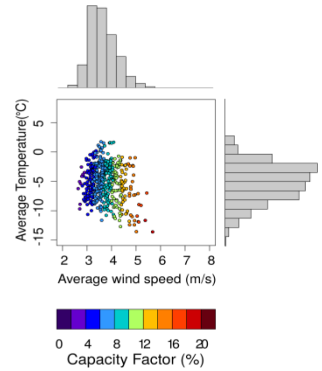
3. Generation of CF seasonal predictions

A) Bias corrected wind speed and temperature



B) CF based on past observations



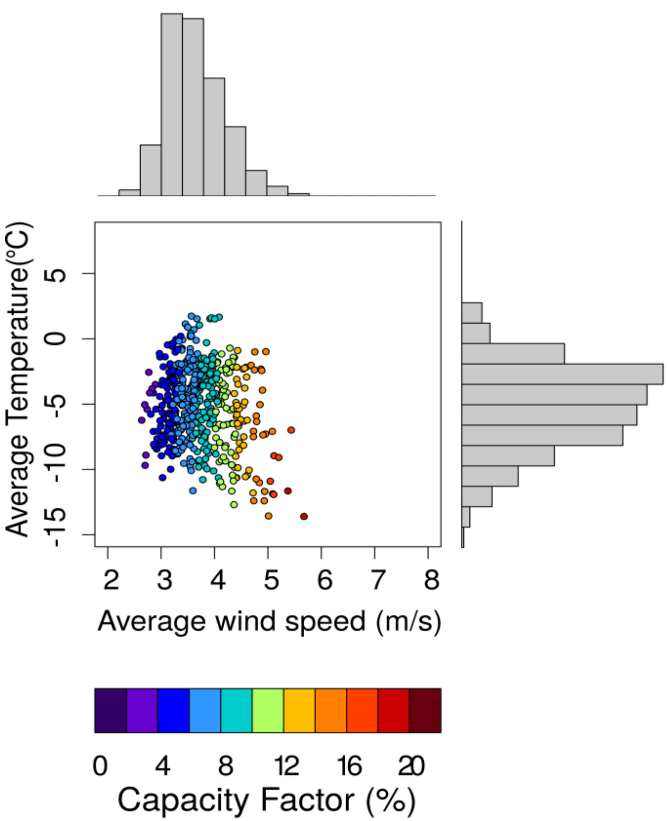
3. Generation of CF seasonal predictions

B) CF based on past observations

MacLeod, D., M. Davis, F. J. Doblas-Reyes, (2014). Modelling wind energy generation potential on seasonal timescales with impact surfaces. SPECS Technical Note No.3, 24 pages.

Capacity Factor

$$CF\,(\%) = \frac{P}{P_{turbine}}$$



Power output curve from Vestas 2 MW

Wind Power:

$$P = \frac{E}{t} = \rho \frac{Av^3}{2} \xrightarrow{\rho = \frac{p}{RT}} P = \frac{p}{RT}\frac{Av^3}{2}$$

Assumptions

1.Wind profile **power law** is used to extrapolate 10m wind speed to the turbine height

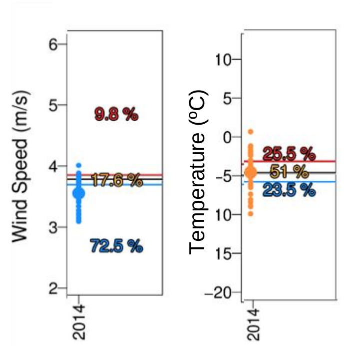
$$\frac{u}{u_r} = \left(\frac{z}{z_r}\right)^a$$

2. Daily variability in 10-m wind speed and operating limitations of a wind turbine has been modelled by a **Rayleigh distribution** (a simple case of the Weibull distribution with k=2).

$$f(x) = \frac{x}{s^2} e^{-x^2/2s^2}$$

3. Generation of CF seasonal predictions

A) Bias corrected wind speed and temperature



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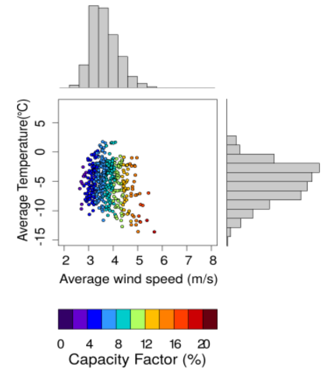

C) Multivariate linear regression model

CF (WS,T) = A WS + B T + C

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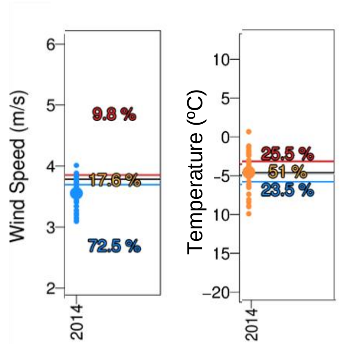
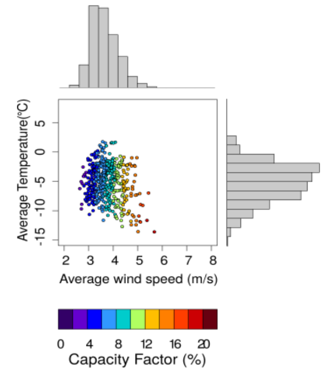
- Past observations of CF, WS and T are fitted to a multivariate regression and the coefficients **A, B and C** are obtained.
- Probabilistic **seasonal predictions of WS and T** are fitted to the regression together with the coefficients A, B, C.
- The generated output is the **probabilistic seasonal prediction of the capacity factor.**
- It has been applied in **cross-validation**

3. Generation of CF seasonal predictions

A) Bias corrected wind speed and temperature



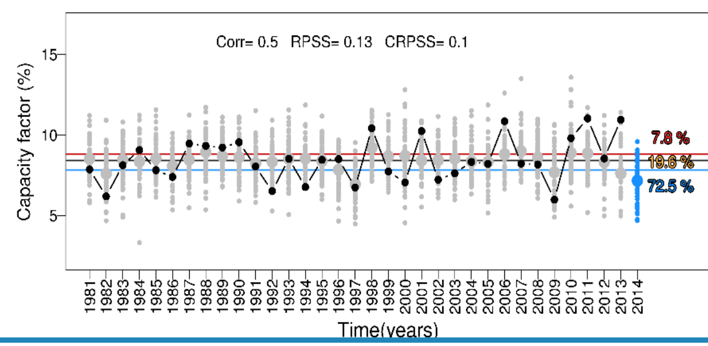
B) CF based on past observations



C) Multivariate linear regression model

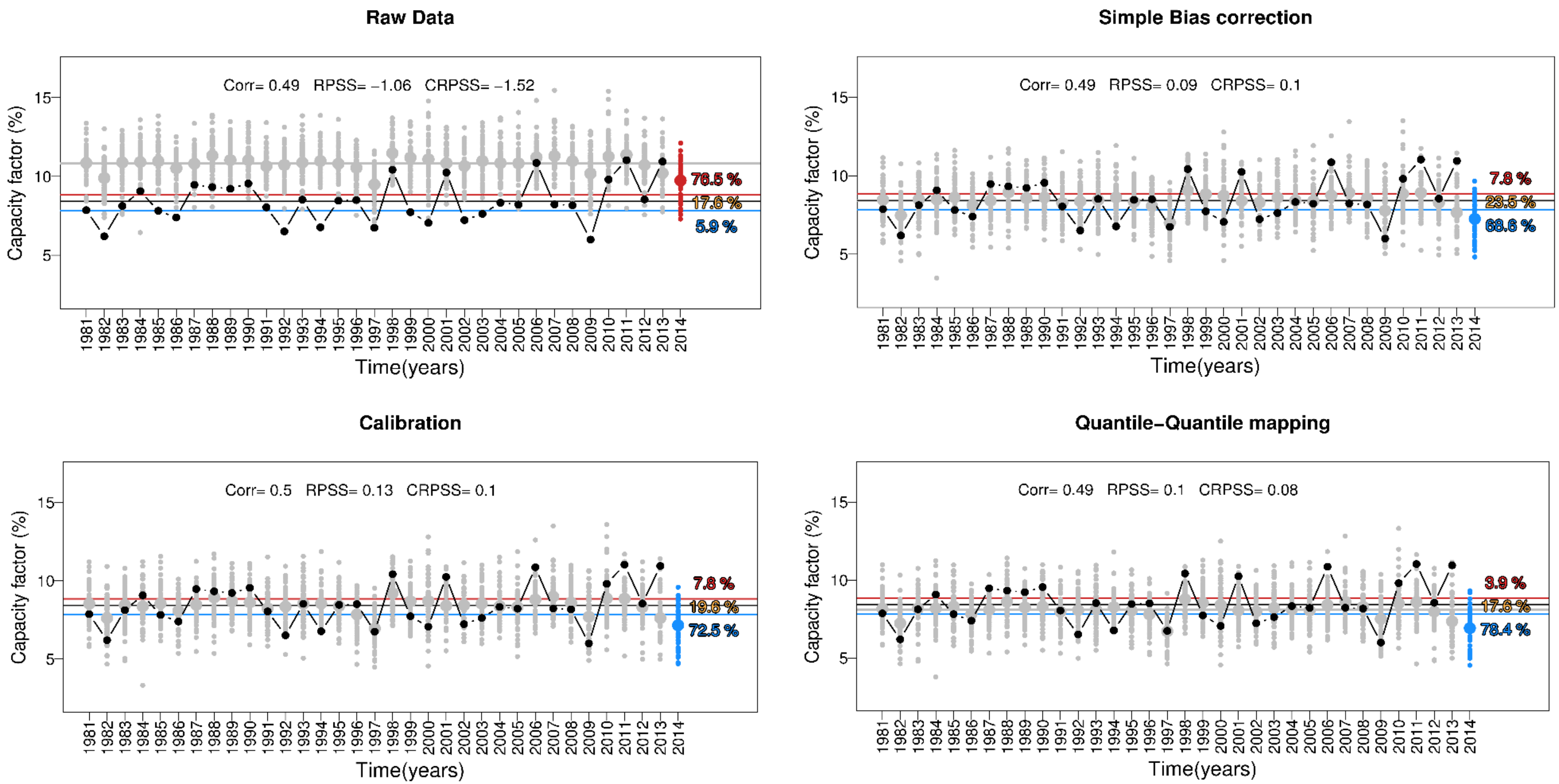
CF (WS,T) = A WS + B T + C

D) Seasonal forecasts of CF



3. Generation of CF seasonal predictions

D) Seasonal predictions of CF



- The transfer model generates bias corrected probabilistic forecasts of capacity factor.
- Seasonal forecasts of capacity factor display positive skill scores which indicates these predictions can add value to the climatology.

Conclusions and prospects

- This study describes a simple methodology to develop **useful information for the wind industry** that can be easily integrated in their decision-making processes.
- Different methods of bias-correction have been used to produce forecasts with **improved forecast quality**.
- The comparison of the three methods indicates that **calibration method displays better reliability** than simple bias correction and quantile mapping.
- Positive skill of CF predictions indicates the **added value** of these forecasts relative to the climatology.
- Future work will focus on the formulation of predictions for specific sites. This is a non-trivial task because the bias-adjustments necessary require long-enough observational references that are not readily available.

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Thank you

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